UPDATE ON THE STABILITY OF FOUR ESTUARIES ON THE AUSTRALIAN SOUTH-EASTERN SEABOARD

Angus Gordon, Coastal Zone Management and Planning, angusczmp@icloud.com
Alexander (Lex) Nielsen, Advisian Worley Group, lex.nielsen@worley.com

INTRODUCTION

On the New South Wales, Australian east coast there are several estuaries with similar characteristics that can be stylized by Figure 1.

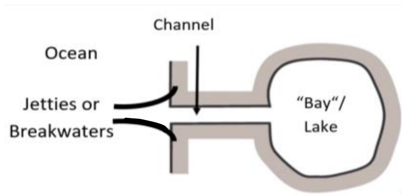

Figure 1 Stylized configuration of estuaries of interest

Disconcertingly, the construction of training walls and jetties (breakwaters) at four of the medium-to-large sized estuaries have tripped their associated channel and lake (bay) systems from a long-term shoaling mode into an unstable scouring mode (Nielsen & Gordon 1980, 2008, 2017; Couriel *et al.* 2013.

THE ESTUARIES

The phenomenon first made its appearance at the twin towns of Forster/Tuncurry on the central NSW coast where the interconnecting road bridge became unstable due to seabed scour at its foundations (Figure 2). Subsequent studies showed that for the many decades since the twin jetty configuration was finally complete (1966) the bay's (Wallis lake's) spring tidal range had been increasing and the phase had been decreasing. Both trends were believed to be indicative of the progressive increases in the efficiencies of the conveyancing capabilities of the ocean entrance and interconnecting channels as channel scour progressed. Since 1990, when consistent and reliable data became available, the bay's spring tidal range has continued to increase at a rate of 1.8 mm/year. By 2015, the ratio of the bay range to that of the ocean had risen from 0.09 to 0.14, a 55% increase, at a rate of 0.0016/a, and showing little signs of abating (Figure 5.1).

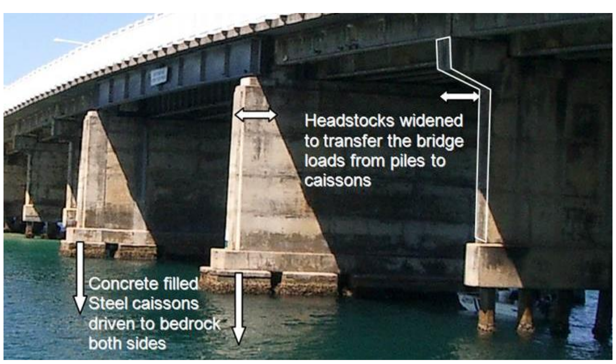

Figure 2 Remediation works for settlement of Foster/Tuncurry road bridge due to channel scour

The increased tidal range of the Lake and interconnecting channels has already had a profound impact on the oyster growing industry and has resulted in some low-lying foreshore dairy farms having to be abandoned due to water logging.

To further investigate the phenomenon a similar channel/lake system with twin breakwaters on the NSW central coast was studied. At Lake Macquarie, the data. For 100 years following jetty construction (1888-1988) the available data suggested the bay/ocean spring tide range ratio had reached 0.080 at an average rate of 0.00080/a. However, for the 18 years following commencement of tidal data acquisition (1988-2006) the average rate was 0.00093/a. But for the past 18 years (2003-2021) the rate rose to 0.00135/a indicating that the rate of increase in the bay/ocean spring tidal range ratio is accelerating (Figure 5.2). At Lake Macquarie not only was the main road bridge undermined but the scour of the lake's connecting channel had compromised the stability of a building, eventually resulting in its collapse into the channel (Figure 3). Low-lying area flooding also is increasing.

Figure 3 Collapse of Foreshore Buildings due to entrance channel scour at Lake Macquarie 8 February 2016 (photo: Fire & Rescue NSW)

To verify the phenomenon further a third channel/lake system, Wagonga Inlet, was identified, this time on the NSW South Coast at Narooma where twin Jetties (breakwaters) had been built in 1976-1978 and reliable tidal data has been available since 1997. Analysis of the tidal data indicated that the spring tidal range has increased steadily over the period of record at an average rate of 3.0 mm/a and the bay-to-ocean spring range ratio has been increasing annually at an average rate of around 0.0033/a The change history of the major spring tidal constituent phase lag is shown on Figure 5.4, indicating a steady reduction of around 0.2°/a. At Wagonga there were no vulnerable near-bank facilities, and the road bridge is some distance upstream so is yet to be impacted by the channel scour. However, unlike the previous two lakes, Wagonga featured extensive areas of seagrass, salt marsh and mangroves all of which had been the subject of previous environmental studies. The data from this information enabled the first opportunity to appreciate the large scale of ecological change that was taking place as a result of the jetty constructions. It provided insights as to what was evolving in the other estuaries and the likely implications for inter-tidal and sub-tidal ecologies at each of the estuaries.

Interestingly, despite the documentation and publication of the potential impacts of likely changes to channel/lake hydrodynamics due to the construction of twin entrance control structures, in the mid 2000s a proposal was developed to artificially alter ("stabilise") the entrance to Lake Illawarra by building a wall out to Windang Island to act as a southern jetty and then, in 2007, constructing a northern jetty to provide a duel jettied entrance. Despite the previous studies and over 25 years of publications on the topic (Nielsen and Gordon ,1980) no Escoffier (1940) analysis was undertaken to determine the likely impacts of the proposed design on the Lake or the interconnecting channel.

As could have been easily anticipated the channel to the Lake immediately began to scour. The first casualty was the road bridge near the entrance which began subsiding (Figure 4). The next was the progressive loss of the foreshore holiday park. Now there are several dwellings under threat. As Figure 5.3 demonstrates, the rate of change in tidal amplitude in the Lake is far greater than seen elsewhere. However, this is possibly due to the early stage of adjustment. Again, the increased tidal range is progressively impacting on low lying areas around the lake and changing the ecological systems.

Figure 4 Placing scour protection around piling at the subsiding Windang Bridge February 2020
(Photo: Phil Hollis)

At all four locations the unintended consequences of jetty construction have been a legacy of on-going financial burden managing the impacts of scour and the environmental costs as deltas extend into the lakes smothering the sea grasses with sand, salt marsh is lost, and mangrove invasion has increased. The overall ecology of the four systems is undergoing a fundamental change, which is impacting not only the vegetation but also the fish and invertebrate habitats. An unexpected benefit has been that sand scoured from the downstream channel has been discharged through the entrance, nourishing the adjacent beach systems.

THE FUTURE AND CLIMATE CHANGE

Utilising an Escoffier (1940) approach and combining it with that of O'Brien (1969) allowed an estimate to be made of the potential time frame required for each estuary to reach a stable configuration (Nielsen & Gordon 2017). Importantly, it was found that, under present conditions the scour phase was likely to continue for many decades if not centuries. It is felt that the studies of channel scour and lake response provided potential insights to the impacts of sea level rise. It is argued that sea level rise will result in increasing water depths in the channels thereby effectively having the same results as an increase in scour and, hence, advancing the rate of repones to changes in entrance efficiency gains. That is, sea level rise will reduce the time required to reach a new stable configuration.

CONCLUSIONS

Field data and hydraulic theory confirm that such estuary entrance works have increased the tidal conveyance of entrance channels by modifying channel cross-sections, removing sand bars, extraneous littoral currents and associated sand movements that, previously, impeded ebb tide discharges and ocean tide forcing (Nielsen & Gordon 2017; Escoffier 1940).

The tidal plane data from four waterways where jetties and training walls have been constructed continue to show a relentless trend for unstable entrance channel scour that will persist for centuries unless tidal choking works are installed. The changes are momentous and appear to be accelerating. The impacts on the ecology of the estuary systems are profound with major changes in habitat, hence, species numbers and diversity. Additionally, there is increased inundation of low-lying land and increased foreshore erosion. Major assets such as bridges that have not been designed in knowledge of the phenomenon subside and become unstable.

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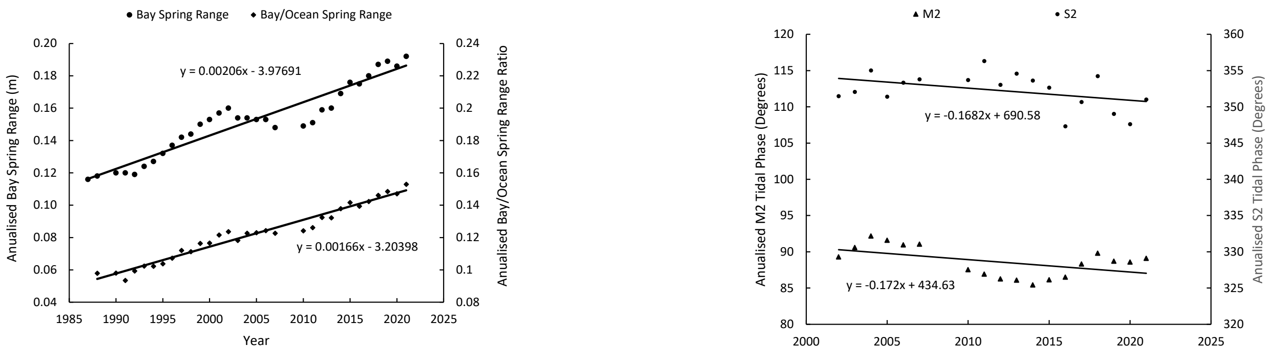
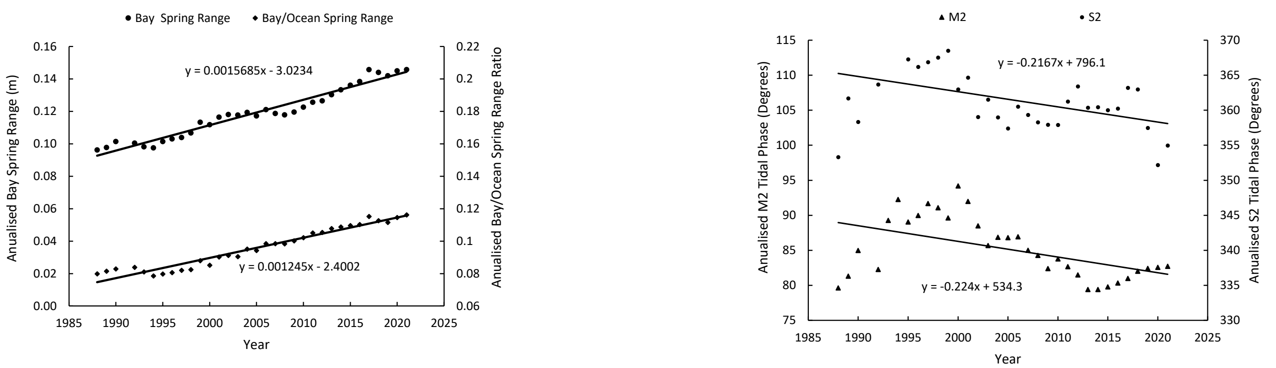
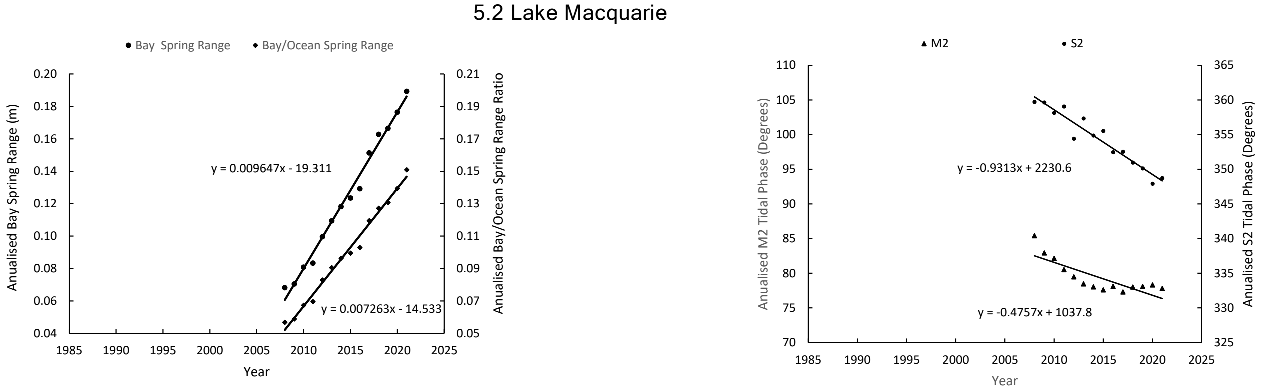


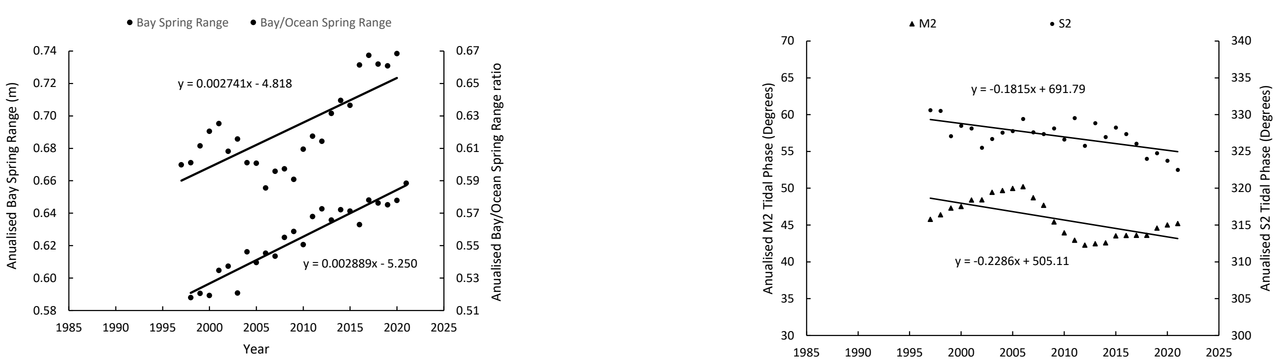
5.1 Wallis Lake



5.2 Lake Macquarie



5.3 Lake Illawarra



5.4 Wagonga Inlet

Figure 5 Histories of spring tidal ranges, bay/ocean range ratios (left) and spring tidal constituents' phase (right) from four bays in NSW Australia where entrance jetties have been constructed, plotted onto consistent scales to allow visual comparison. However, it is evident that to characterise the tide accurately, 18.6 year data cycles are required. The Authors wish to acknowledge that the data for these studies was provided by Manly Hydraulics Laboratory, NSW Department of Planning and Environment